

COLLEGE OF  
OCEANIC &  
ATMOSPHERE SCIENCES



OREGON  
STATE  
UNIVERSITY

104 Ocean Admin Building  
Corvallis, Oregon  
97331-5503

Dr. Ronald Ferek  
Office of Naval Research  
800 North Quincy Street,  
Ballston Tower One  
Arlington, VA 22217-5660

9 July, 1998

ONR Grant # N00014-95-1-0405  
OSU # N0063A

Dear Ron,

In order to complete my ONR grant entitled, "Survey of ship tracks observed by NOAA AVHRR," I am sending three copies of the Final Technical Report to you with copies distributed as indicated below. Included is a completed Report Documentation Page (SF 298).

Sincerely,

A handwritten signature in black ink, appearing to read "James A. Coakley, Jr." The signature is fluid and cursive.

James A. Coakley, Jr.

Defense Technical Information Center (2 copies)  
8725 John J Kingman Rd, Suite 0944  
Ft. Belvoir VA 22060-6218

Administrative Contracting Officer (1 copy)  
Office of Naval Research  
Seattle Regional Office  
1107 NE 45th Street, Suite 350  
Seattle, WA 98105-4631

Telephone  
541-737-3504  
  
Fax  
541-737-2064

Director, Naval Research Laboratory (1 copy)  
Attn: Code 2627  
Washington DC 20375

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED	
	9 July 1998	Final Technical Rept. 1Feb95 - 31Jan97	
4. TITLE AND SUBTITLE		5. FUNDING NUMBERS	
Survey of Ship Tracks Observed by NOAA AVHRR			
6. AUTHOR(S)			
James A. Coakley, Jr.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)		8. PERFORMING ORGANIZATION REPORT NUMBER	
Oregon State University Corvallis, OR 97331		N0063A	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
Office of Naval Research Ballston Center Tower One 800 North Quincy Street Arlington, VA 22217-5660		N00014-95-0405	
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT			
Unlimited Public Access			
19980729 112			
13. ABSTRACT (Maximum 200 words)			
<p>High resolution, multispectral satellite imagery data from morning and afternoon satellite passes over the coast of California during June 1994 were analyzed to determine the altitudes, visible optical depths, and cloud droplet effective radii for low-level clouds. Comparisons were made between the properties of clouds within 50 km of the tracks left by underlying ships in the clouds and those farther than 200 km from the tracks in order to deduce whether any special conditions were required for the appearance of ship tracks in satellite images. The results indicated that: 1) ship tracks rarely appeared in low-level clouds having altitudes greater than 1 km; 2) small cloud droplet sizes and large liquid water paths did not seem to restrict the appearance of ship tracks as was suggested by theory, and 3) ship tracks were more frequent when clouds at altitudes below 1 km were extensive and completely covered large areas, as was more frequently the case in the morning.</p>			
14. SUBJECT TERMS		15. NUMBER OF PAGES	
Ship tracks, remote sensing, cloud properties		2	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

## FINAL TECHNICAL REPORT

ONR Grant # N00014-95-1-0405

### SURVEY OF SHIP TRACKS OBSERVED BY NOAA AVHRR

James A. Coakley, Jr.

College of Oceanic and Atmospheric Sciences

Ocean Admin 104

Oregon State University

Corvallis, OR 97331-5503

1-km Advanced Very High Resolution Radiometer (AVHRR) observations from the morning, NOAA-12, and afternoon, NOAA-11, satellite passes over the coast of California during June 1994 were analyzed to determine the altitudes, visible optical depths, and cloud droplet effective radii for low-level clouds. Comparisons were made between the properties of clouds within 50 km of ship tracks and those farther than 200 km from the tracks in order to deduce whether any special conditions were required for the appearance of ship tracks in satellite images. The results indicated that the low-level clouds must be sufficiently close to the surface for ship tracks to form. Ship tracks rarely appeared in low-level clouds having altitudes greater than 1 km. Contrary to what might be suggested from theories concerning the susceptibility of cloud modification due to increases in the number of particles in the environment, the distributions of visible optical depths and cloud droplet effective radii for ambient clouds in which ship tracks were imbedded were found to be the same as those for clouds without ship tracks. Cloud droplet sizes and liquid water paths for low-level clouds do not seem to constrain the appearance of ship tracks in the imagery. The sensitivity of ship tracks to cloud altitude appears to explain why the majority of ship tracks observed from satellites off the coast of California were found south of 35°N. A small rise in the height of low-level clouds appeared to explain why numerous ship tracks appeared on one day in a particular region, but disappeared on the next, even though the altitudes of the low-level clouds were generally less than 1 km and the cloud cover was the same for both days. In addition, ship tracks were frequent when low-level clouds at altitudes below 1 km were extensive and completely covered large areas. The frequency of imagery pixels overcast by clouds with altitudes below 1 km is greater in the morning than in the afternoon and this difference explained why more ship tracks were observed in the morning than in the afternoon. If the occurrence of ship tracks in satellite imagery data depends on the coupling of the clouds to the underlying boundary layer, then cloud top altitude and the area of complete overcast by low-level clouds may be useful indices for this coupling.

List of publications that were a result of this research project.

Coakley, J.A., Jr., P.A. Durkee, K. Nielsen, J.P. Taylor, S. Platnick, B.A. Albrecht, D. Babb, F-L.

Chang, W.R. Tahnk, C.S. Bretherton, and P.V. Hobbs , 1997: The appearance and

disappearance of ship tracks on large spatial scales. *J. Atmos. Sci.* (Accepted for

publication).

Taylor, J.P., M.D. Glew, J.A. Coakley, Jr., W.R. Tahnk, S. Platnick, P.V. Hobbs and R.J. Ferek,  
1997: The effects of aerosols on the radiative properties of clouds. *J. Atmos. Sci.*  
(accepted for publication)